REMARKS

Claims 1-9, 11-14, 16-19 and 21-30 are pending in this application. Claims 1 and 17 have been amended. Claims 15 and 20 have been canceled and their subject matter has been incorporated in amended independent claims 1 and 17, respectively. No new matter has been introduced.

Claims 1-6, 9, 11-13 and 16 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Jiang et al. (U.S. Pub. No. US 2002/0009880 A1) ("Jiang") in view of Lopatin et al. (U.S. Patent No. 6,368,954 B1) ("Lopatin") and Applicant's Admitted Prior Art ("Prior Art"). This rejection is respectfully traversed.

The claimed invention relates to a method of forming a copper damascene structure. As such, amended independent claim 1 recites a "method of forming a copper damascene structure" by *inter alia* "patterning a low-dielectric constant layer to form at least one opening" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions." Amended independent claim 1 further recites "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "providing a copper layer in said at least one opening and in contact with said tungsten nitride layer." Amended independent claim 1 also recites that "said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition."

Jiang relates to a "copper interconnect having a barrier layer (106, 206)." (Abstract). According to Jiang, the barrier layer is "a silicon containing metal barrier layer." (¶ [0006] at lines 1-2). Jiang emphasizes that the "silicon containing diffusion barrier 206 has low resistance and excellent wettability to Cu and to dielectrics such as FSG." Jiang teaches that "[c]opper is then deposited over the silicon containing barrier layer." (¶ [0006] at lines 6-7).

Lopatin relates to a copper interconnect using atomic layer deposition. (Title; Abstract). According to Lopatin, the interconnect structure has "a barrier layer formed over a patterned semiconductor substrate using atomic layer deposition; a pre-seed layer formed using atomic layer epitaxy; a thick seed layer; a bulk copper interconnect layer; and a top sealing layer." (Col. 3, lines 25-30). Lopatin teaches the steps of "depositing a layer of barrier material over said surface using atomic layer deposition; depositing a pre-seed layer of conducting material using atomic layer epitaxy; depositing a seed layer of conducting material" and "depositing a bulk interconnect layer." (Col. 3, lines 30-37).

The subject matter of claims 1-6, 9, 11-13 and 16 would not have been obvious over Jiang in view of Lopatin and the Prior Art. Specifically, the Office Action fails to establish a *prima facie* case of obviousness. Courts have generally recognized that a showing of a *prima facie* case of obviousness necessitates three requirements: (i) some suggestion or motivation, either in the references themselves or in the knowledge of a person of ordinary skill in the art, to modify the reference or combine the reference teachings; (ii) a reasonable expectation of success; and (iii) the prior art references must teach or suggest all claim limitations. See e.g., In re Dembiczak, 175 F.3d 994, 50 U.S.P.Q.2d 1614 (Fed. Cir. 1999); In re Rouffet, 149 F.3d 1350, 1355, 47 U.S.P.Q.2d 1453, 1456 (Fed. Cir. 1998); Pro-Mold & Tool Co. v. Great Lakes Plastics, Inc., 75 F.3d 1568, 1573, 37 U.S.P.Q.2d 1626, 1630 (Fed. Cir. 1996).

First, not all limitations of amended independent claim 1 are taught or suggested by the prior art, whether considered alone or in combination. None of Jiang, Lopatin and the Prior Art, considered alone or in combination, teaches or suggests "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions,*" "*removing horizontal portions of said tungsten nitride layer* formed above a surface of said low-dielectric constant layer *by chemical mechanical polishing,*" and "providing a copper layer . . . *selectively deposited by low-temperature metal-organic chemical vapor deposition,*" as amended independent claim 1 recites (emphasis

added).

As noted above, Jiang relates to "a silicon containing metal barrier layer" (¶[0006] at lines 1-2), and not to "a tungsten nitride layer," much less to the formation of "a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," as amended independent claim 1 recites. Jiang also fails to teach or suggest "removing horizontal portions of said tungsten nitride layer" above a surface of the dielectric layer and "*subsequently* providing a copper layer in said at least one opening," as amended independent claim 1 further recite. Jiang specifically teaches that "a copper layer 110 is formed on the barrier layer 206" and that the "copper layer 110 *and* barrier layer 206 are then removed back." (¶ [0033] at lines 1-2; Figure 4D; ¶ [0034] at lines 1-2; Figure 3) (emphasis added). Thus, Jiang teaches that the copper layer 110, which would arguably correspond to the copper layer of the claimed invention, is provided prior to the chemical mechanical polishing process and not "subsequent" to it, as in the claimed invention.

Similarly, Lopatin fails to teach or suggest "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," as amended independent claim 1 recites. Lopatin also fails to teach or suggest "providing a copper layer . . . selectively deposited by *low-temperature metal-organic chemical vapor deposition*," as amended independent claim 1 recites (emphasis added). In Lopatin, the pre-seed layer of conducting material is formed over the barrier layer using atomic layer epitaxy, and not selective deposition by low-temperature metal-organic chemical vapor deposition, as in the claimed invention. (Col. 3, lines 30-37). Lopatin also fails to teach or suggest "removing horizontal portions of said tungsten nitride layer" above a surface of the dielectric layer and "*subsequently* providing a copper layer in said at least one opening," as amended independent claim 1 recites. As clearly illustrated in Figures 5-9 of Lopatin, the removal of any horizontal portions of the barrier layer 401, which would arguably correspond to the tungsten nitride layer of the claimed invention, occurs only *subsequent to* the copper deposition, and not *prior to* it, as in the claimed invention.

Further, the Prior Art fails to teach or suggest all limitations of amended independent claim 1. The Prior Art does not teach or suggest a "method of forming a copper damascene structure" by *inter alia* "patterning a low-dielectric constant layer to form at least one opening," "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions" and "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing," as amended independent claim 1 recites.

Second, a person skilled in the art would not have been motivated to combine the teachings of Jiang with those of Lopatin, as the Examiner asserts. The crux of Jiang is the formation of a "a silicon containing metal barrier layer" by a specific co-deposition method which "gives total flexibility of the Si concentration in the barrier film 106." (¶ [0006] at lines 1-2; ¶ [0021]). Jiang specifies that the "method for forming the silicon containing barrier is an in-situ process that allows higher throughput than ex-situ process." (¶[0022]). In contrast, the crux of Lopatin is the formation of a copper interconnect by atomic layer deposition. For this, Lopatin teaches the formation of tungsten nitride barrier layer 401 by atomic layer deposition and of the pre-seed layer 402 by atomic layer epitaxy. (Col. 5, lines 29-43). Thus, one skilled in the art would not have been motivated to combine Lopatin, which teaches the formation of barrier and copper layers by *ex-situ* atomic layer deposition and epitaxy processes, with Jiang, which teaches the formation of barrier and copper layers by an *in-situ* process. For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 1-6, 9, 11-13 and 16 is respectfully requested.

Claims 7 and 8 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Jiang in view of Lopatin, the Prior Art and Farrar (U.S. Pub. No. US 2002/0048931 A1). This rejection is respectfully traversed.

Claims 7 and 8 depend on amended independent claim 1 and recite that the low-dielectric constant layer "is formed by spin coating to a thickness of about 2,000

to 50,000 Angstroms" (claim 7) and "to a thickness of about 5,000 to 20,000 Angstroms" (claim 8).

Farrar relates to a "damascene structure with a plurality of low dielectric constant insulating layers acting as etch stops." (Abstract). According to Farrar, the low dielectric constant materials "have similar methods of formation and similar capacities to withstand physical and thermal stress" and "act as insulating layers through which trenches and vias are formed." (Abstract). Farrar also teaches barrier layer 72 formed of "metals, such as titanium (Ti), zirconium (Zr), tungsten (W), or hafnium (Hf), or metal compounds, such as tantalum nitride (TaN) or silicon nitride ($Si_3 N_4$)." (¶ [0046] at lines 1-4).

The subject matter of claims 7 and 8would not have been obvious over Jiang in view of Lopatin, the Prior Art and Farrar. The Office Action fails again to establish a *prima facie* case of obviousness. Jiang, Lopatin, the Prior Art and Farrar, whether considered alone or in combination, fail to teach or suggest all limitations of amended independent claim 1 and of dependent claims 7 and 8.

None of Jiang, Lopatin or the Prior Art teaches or suggests "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions,*" "*removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing*" and "providing a copper layer . . . selectively deposited by *low-temperature metal-organic chemical vapor deposition,*" as amended independent claim 1 recites (emphasis added).

Farrar teaches that "the barrier layer 72 is simultaneously deposited in both the via 65 and the trench 67" (¶ [0047] at lines 2-6) and that "*a conductive material 80 is next deposited* to fill in both the via 65 and the trench 67." (¶ [0048] at lines 1-2) (emphasis added). Accordingly, Farrar is entirely silent about "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer," much less about "*subsequently* providing a copper layer in said at least one opening," as amended independent claim 1 recites (emphasis added).

For at least these reasons, the Office Action fails to establish a prima facie case of obviousness and withdrawal of the rejection of claims 7 and 8 is respectfully requested.

Claims 14, 17-20, 23 and 28-30 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Jiang in view of Lopatin, the Prior Art and Liu et al. (U.S. Patent No. 6,010,962) ("Liu"). This rejection is respectfully traversed.

As noted above, the claimed invention relates to a method of forming a copper damascene structure. As such, independent claim 14 recites a "method of forming a copper damascene structure" by *inter alia* "patterning a low-dielectric constant layer to form at least one opening through said low-dielectric constant layer" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions." Independent claim 14 further recites "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "subsequently providing a copper layer in said at least one opening . . . by contact displacement copper deposition at room temperature."

Amended independent claim 17 recites a "method of forming a copper damascene structure" by *inter alia* "forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetra-methyl-ammonium hydroxide solution" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening." Amended independent claim 17 also recites "subsequently removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer" and "providing a copper layer in said at least one opening."

Liu relates to a method for forming inlaid copper interconnects. (Abstract). According to Liu, a conformal blanket barrier layer is formed over a composite groove/hole structure already formed in an insulating layer, and then a copper seed

layer is grown over the barrier layer. "A layer of photoresist is next deposited over the substrate filling the composite structure. The photoresist layer, seed layer and the barrier layer are then removed by chemical-mechanical polishing, leaving the seed layer and the barrier layer on the inside walls of the composite structure, however." (Abstract). Liu also teaches that "the photoresist is removed . . . and replaced . . . with electroless plated copper, which forms a dome-like protrusion extending from the composite structure." (Abstract).

The subject matter of independent claim 14 and amended independent claim 17 would not have been obvious over Jiang in view of Lopatin, the Prior Art and Liu. None of Jiang, Lopatin or the Prior Art teaches or suggests "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "subsequently providing a copper layer in said at least one opening . . . by contact displacement copper deposition at room temperature," as independent claim 14 recites. The cited references also fail to teach or suggest "forming a material layer of methylsilsequiazane over a substrate," "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions" and "subsequently removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer," as amended independent claim 17 recites.

In addition, Liu fails to teach or suggest "forming a *tungsten nitride layer* by atomic-layer deposition using sequential surface reactions," as claims 14 and 17 recite. Layer 170 of Liu, which would arguably correspond to the tungsten nitride layer of the claimed invention, is described as a "tantalum barrier (170)," and not as a "tungsten nitride layer," much less as a "tungsten nitride layer" formed "by atomic-layer deposition using sequential surface reactions," as in the claimed invention.

Liu also fails to teach or suggest the steps of "patterning a low-dielectric constant layer to form at least one opening through said low-dielectric constant layer"

(claim 14) or "forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetra-methyl-ammonium hydroxide solution" (claim 17). In fact, Liu mentions that lower layer dielectric (LLD) (110) and upper layer (ULD) (130) "may be formed from materials including but not limited to silicon oxide materials, silicon nitride materials, and silicon oxynitrides materials formed within integrated circuits through methods including but not limited do CVD, PECVD, PVD sputtering methods, and others known as PEOX, PETEOS, or low-k materials, FSG, HSQ Flare and PAE2." (Col. 5, lines 45-52). Although Liu mentions "low-k materials" as part of the extensive list of materials for the dielectric layers 110, 130, Liu specifically emphasizes that "[f]or the preferred embodiment of the present invention, LLD layer (110) comprises PECVD oxide" and that "ULD LAYER (130) comprises PECVD oxide" also. (Col. 5, lines 52-57).

Further, one skilled in the art would not have been motivated to combine the teachings of Jiang and Lopatin with those of Liu, as the Examiner asserts. As noted above, the crux of Jiang is the formation of "a silicon containing metal barrier layer" by a specific co-deposition method which "gives total flexibility of the Si concentration in the barrier film 106." (¶ [0006] at lines 1-2; ¶ [0021]). The crux of Lopatin is the formation of a copper interconnect by atomic layer deposition. The crux of Liu is a method of "forming copper interconnects without dishing defects through a judicious use of a modified CMP process." (Col. 3, lines 58-60). It is clear, therefore, that the only structure which Jiang, Lopatin and Liu have in common is the substrate on which their respective structures are formed. Thus, one skilled in the art would not have been motivated to combine the *ex-situ* atomic layer deposition and epitaxy processes of Lopatin, with the *in-situ* process for barrier and copper layers of Jiang, and further with the modified CMP process of Liu for avoiding dishing defects. For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 14, 17-20, 23 and 28-30 is respectfully requested.

Claims 21, 22 and 24-27 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Jiang in view of Lopatin, the Prior Art, Liu and Farrar. This rejection is respectfully traversed. Applicant notes that claims 21, 22 and 24-27 depend on amended independent claim 17 and for the reasons noted above with respect to the amended independent claim 17, the cited references also fail to teach or suggest all limitations of dependent claims 21, 22 and 24-27. Accordingly, withdrawal of the rejection of these claims is also respectfully requested.

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to withdraw the outstanding rejection of the claims and to pass this application to issue.

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Respectfully submitted,

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